BUTTERS & PETERSON

Evaporation of Water Under the Boiling Point

Mechanical Engineering

B. S.

1911

UNIV OF
ILLINOIS
LIBRARY

UNIVERSITY OF ILLINOIS
LIBRARY

Class 1911 Book B98 Volume C

EVAPORATION OF WATER UNDER THE BOILING POINT

BY

HOWARD MONREAU BUTTERS
ERLE SHERMAN PETERSON

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1911

1911
B93

UNIVERSITY OF ILLINOIS

May 29 1911

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Howard Monrau Butters and Erle Sherman Peterson

ENTITLED Evaporation of Water Under the Boiling Point

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

H. S. Goderre

Instructor in Charge.

APPROVED: A. N. Goodenough

HEAD OF DEPARTMENT OF Mechanical Engineering

197568

Digitized by the Internet Archive
in 2013

http://archive.org/details/evaporationofwat00butt

TABLE OF CONTENTS.

Introduction	Page 1
Object	" 2
Previous Work on the Same Subject	" 2
Description of Tests	" 6
Description of Apparatus	" 7
Description of Method and Operation	" 8
Conclusions	" 10
Diagrams	" 11
Tabulated Data	" 14
Data Sheets	" 15
Curves	" 25
Graphical Logs	" 30

EVAPORATION OF WATER UNDER THE BOILING POINT.

The general outline to be followed in the presentation of this thesis will be arranged in the following order:

A.- INTRODUCTION

B.- OBJECT

C.- PREVIOUS WORK ON THE SAME SUBJECT

D.- DESCRIPTION OF TESTS

(a) Description of Apparatus

(b) Description of Method and Operation

E.- CONCLUSIONS

F.- DIAGRAMS

G.- TABLES AND DATA SHEETS

H.- CURVES AND GRAPHICAL LOGS

EVAPORATION OF WATER UNDER THE BOILING POINT.

A.- INTRODUCTION.

Owing to the very small amount of general information concerning the rate of the evaporation of water at temperatures above that of the atmosphere, nothing definite is known concerning the error in determining the water rate of an engine by the present method. The work carried on previous to this was merely to determine the relation of rain fall to run off.

In determining the water rate of an engine it is necessary to weigh the condensate which is at a temperature considerably above that of the atmosphere. The condensate is usually collected in such a way that it is exposed to the air. George W. Rafter in his notes on the relation of rainfall to run off says, "there is always a condensation of moisture from the air going on at the surface of the water, and at the same time there is going on a loss of moisture from the water surface by evaporation. The intensity of both these operations depends upon the differences of the temperatures of the air and the water surface with which it may be in contact. When the temperature of both the air and the water are the same the phenomena stop." The temperature of the condensate is usually above that of the air so from the above statement it must necessarily follow that there will be a loss due to moisture leaving the surface of the water.

B.- OBJECT.

The object of this thesis is to determine:

1. The rate of the evaporation of water at different temperatures in regard to the amount of surface exposed.

2. The amount of water evaporated per degree difference of temperature of the exposed water and the air.

3. The effect of the humidity of the air upon the amount of water evaporated.

C.- PREVIOUS WORK ON THE SAME SUBJECT.

An investigation of the evaporation of water as regards the relation of rainfall to run off was started at Lake Tahoe during the month of May in 1900 by Mr. Jospeh Barlow Lippincott. A galvanized iron tank two feet square and two feet deep was placed in the lake at its outlet where it would be protected from the heavy waves. A finely divided scale was placed in the tank and daily readings were taken at about the same hour. The tank was at all times kept full within a few inches of the top, so the water would be fully exposed to the wind and the sun. The following data give the results of this test:

	Evaporation in inches
May 17 to 31	1.83
June	3.80
July	4.00
August	5.15
September	3.10
October	2.15
November	1.38
Total,	21.41

In 1894 similar tests were carried on at Reno, Nevada, with a view to determining approximately the amount of evaporation at that point. A small galvanized iron tank was placed in the ground and kept filled to within an inch of the top at all times. These results are given below:

Results from Tests at Reno, Nevada.

	Evaporation in inches
May 11 to 31	2.80
June	5.35
July	8.45
August	9.12
September	7.44
October	4.31
November	2.75
Total,	40.22

The following is a table of the amount of the evaporation, wind movement, humidity,and temperature at the Sweetwater reservoir for a series of years:

Period	Evap., inches	Wind, miles per hour	Humidity	Temperature of air, °F	Temperature of water, °F
1889-90	56.47	4.9	--	--	--
1890-91	57.54	4.6	--	--	--
1891-92	58.65	4.8	72	61	68
1892-93	49.60	4.9	68	61	67
1893-94	48.68	5.1	70	60	67
1894-95	46.31	5.2	79	59	--
1895-96	45.18	5.2	71	61	--
1896-97 (a)	41.24	5.3	76	61	--
1897-98	61.93	5.9	73	60	--
1898-99 (b)	32.54	5.8	72	59	--

Note:- (a) Evaporation from January 1 to August 31.
(b) Evaporation from September 1 to April 30.

The following table gives results obtained from experiments at Reeder's Lake in Kern County. The system used was similar to that employed at Lake Tahoe and at Reno:

Date	Time of day	Temp. water in pan, °F	Temp. air °F	Evap., depth in feet	Evap., depth for 24 hrs. in feet
June 23	9:55 A.M.	--	--	-----	------
June 23-25	6:25 A.M.	83	92	0.040	0.0168
June 25-28	7:50 P.M.	81	90	0.068	0.0222
June 28-30	5:00 P.M.	82	79	0.035	0.0187
June 30-July 5	4:50 P.M.	87	73	0.096	0.0192
July 5-8	5:00 P.M.	92	77	0.072	0.0240
June 23 to July 8, totals, ...				0.311	0.1009

The results of experiments from July 9 to August 20 in the Panama Slough in Kern County are given in the following table:

Date	Time of day	Temp. water in pan, °F	Temp. air °F	Evap., depth in feet	Evap., depth for 24 hrs., in feet
July 9	12:30 P.M.	--	--	-----	------
July 9-11	6:20 P.M.	72	76	0.030	0.0134
July 11-21	9:00 A.M.	--	--	-----	------
July 21-24	6:50 P.M.	--	88	0.037	0.0108
July 24-29	6:15 P.M.	76	88	0.054	0.0108
July 29-Aug.5	7:00 P.M.	79	92	-----	------
Aug.5-13	7:00 A.M.	72	76	-----	------
Aug.13-20	6:45 A.M.	64	68	0.084	0.0120
July 9 to August 20 (approximate)				0.490	0.0166

Kent in his Pocket Book for Mechanical Engineers gives the following table as the result of experiments at the Mount Hope Reservoir in Rochester, New York:

Mean temp. of air	Mean temp. of water	Mean humidity of air	Evaporation in inches	Rainfall in inches
70.5	68.2	67.0	5.59	3.44
70.3	70.2	74.6	4.93	2.95
68.7	66.1	75.2	4.05	1.44
53.3	54.4	74.7	3.23	2.16

He also gives the following results from Tulare County, California, from 1881 to 1885:

Average evaporation from a pan in the river, 1/8 inch per day throughout the year.
Average evaporation from a pan in the air, 3/16 inch per day throughout the year.
Average evaporation for August, 1/3 inch per day, in air.
Average evaporation for April and March, 1/12 inch per day, in air.

From these data it can be seen that all the experiments give results which cannot be applied to temperatures above that of the atmosphere. These data, however, give a general idea as to the rate

of evaporation that might be expected. So in weighing the condensate from an engine to determine its water rate it is natural to suppose that an error due to a loss by evaporation appears. But the temperature of the condensed steam is anywhere from that of the atmosphere to that of the boiling pointand, therefore, the results given above cannot be used.

D.- DESCRIPTION OF TESTS.

The following tests were made on three different sized and different shaped tanks, and were conducted in a corner of the laboratory where the conditions of the variations of the air currents would not be noticeable. The method pursued in the experimental work of this thesis was as follows:

The amount of evaporation at different temperatures was determined by weighing a tank of the exposed water. The temperature of the water was kept constant by means of a steam coil. The evaporation was allowed to go on by free exposure to the air.

In conducting the test, the following observations were made hourly:

1. Reading of scale.
2. Temperature of the water.
3. Temperature of the room.
4. Readings of the wet and dry bulb thermometers.

In order to determine how nearly the conditions remained uniform during the test, barometer readings were taken. These were taken at less frequent intervals.

On some tests, especially those at the lower temperatures, the tests were run for ten hours, while at the higher temperatures they

were run from six to seven hours.

(a) Description of Apparatus.

The apparatus used consisted of the following:

1. Three tanks.
2. Thermostat.
3. Platform scales.
4. Wet and dry bulb hygrometer.
5. Two thermometers.
6. Steam coils.

1. The tanks used were of different sizes and shapes. One was rectangular, giving an exposed area of 26.35 square feet. The other two were oblong, giving an exposed area of 23.15 square feet and 16.52 square feet respectively. These areas allow for the amount of surface taken up by the steam pipes and the temperature regulator.

2. The thermostat was a number ten water temperature regulator manufactured by the Powers Regulator Company of Chicago. The regulator worked on the principle of the expansion of a rod which by means of a system of levers admitted or released compressed air to and from a diaphragm valve. This expansion rod was placed in the water, and one end was threaded and incased in a metal box. Attached to the threaded end was a collar which carried a steel strip leading to the air main as shown in the diagram on page 13. This strip was fulcrumed by a spring and, fastened to the end leading to the air main, was a needle valve. When the rod expanded due to an increase of temperature, the steel strip was forced out and by acting on the spring as a fulcrum the needle valve closed, admitting air to the diaphragm valve and closing it down. When the rod contracted due to cooling

of the water the reverse happened and the needle valve allowed the air to escape, thus releasing the pressure in the diaphragm valve, allowing it to open and admit more steam to the heating coil. Air pressure at about fifteen pounds per square inch was used.

3. The scale used was an ordinary platform scale of very good make and very sensitive, having a capacity of 3500 pounds.

4. The hygrometer used was one of the ordinary wet and dry bulb variety, the mercury bulb of the wet bulb thermometer being incased in a wicking saturated at all times with water.

5. The two thermometers used were one for room temperature reading from 0 to 100 degrees Fahrenheit, and one for determining the temperature of the water reading from 0 to 220 degrees Fahrenheit. This latter thermometer was calibrated by use of a standard.

6. A steam coil was made and suspended in the tank as shown in the diagram on pages 11-12. This coil was made of 3/4 inch pipe. The vertical parts were encased in 1 1/2 inch pipes to keep the water from coming in contact with the naked pipe.

(b) Description of Method and Operation.

In making this investigation conditions similar to those of an engine test were maintained in so far as possible. In order to secure data which could be reduced to a common basis, a constant temperature was kept throughout the entire test, which is not the case in an engine test. At twenty five degree intervals different temperatures were maintained throughout a range of one hundred degrees. To keep the temperature constant a steam coil was placed in the bottom of the tanks used, steam introduced and controlled by the temperature regulator. This regulator was not exactly accurate, as the variation

in temperature amounted to about one degree. The temperature over the surface of the water varied almost unnoticeably. At the higher temperatures boiling took place about the naked steam pipes where they entered the water and a sleeve of larger size pipe was used for a covering, thus eliminating the boiling entirely.

A galvanized iron tank was used and placed upon the platform scales. Investigation showed that the displacement of the water by the coil, and the different depths of the water upon the coil, made practically no difference in the weight upon the scale. This was true because the coil was suspended at each end from above and no part of it was allowed to bear on the scales.

Since the temperatures of the water did not vary but slightly, an average temperature was secured from the hourly readings.

To discover what effect the humidity of the air had on the evaporation, a wet and dry bulb hygrometer was used for the determination of the humidity. In order to determine the effect of the humidity, duplicate tests were run of several tests, on different days.

There was considerable difficulty in determining the relative humidity, as the thermometers were very sensitive to the changes of temperature, and a slight change in the difference of the two bulb readings gives a large change in the humidity, and this humidity does not at once act upon the water surface. On account of this it was deemed best to compare the rate of evaporation to the differences of the bulb readings.

The effect of the size and the shape of surface was also considered.

In order to reduce the amounts ovaporated to a common basis for comparison, they were reduced to pounds per square foot per hour and to pounds per square foot per hour per degree difference in temperature between that of the air and that of the water.

E.- CONCLUSIONS.

From the data and the curves shown, the following conclusions are deduced:

1. The evaporation increases as the temperatures increase. At the lower temperatures this increase appears to be directly proportional, but as the temperatures increase very much, the evaporation increases more rapidly.

2. The evaporation increases as the humidity decreases.

3. The evaporation increases as the differences of the dry and wet bulb readings vary, that is, the greater the variation the greater the amount of evaporation.

4. The evaporation is proportional to the difference of the temperatures of the air and the water.

5. When reduced to a common basis the amount of evaporation is independent of the shape or the size of the exposed surface.

DIAGRAM OF APPARATUS.

PLAN.

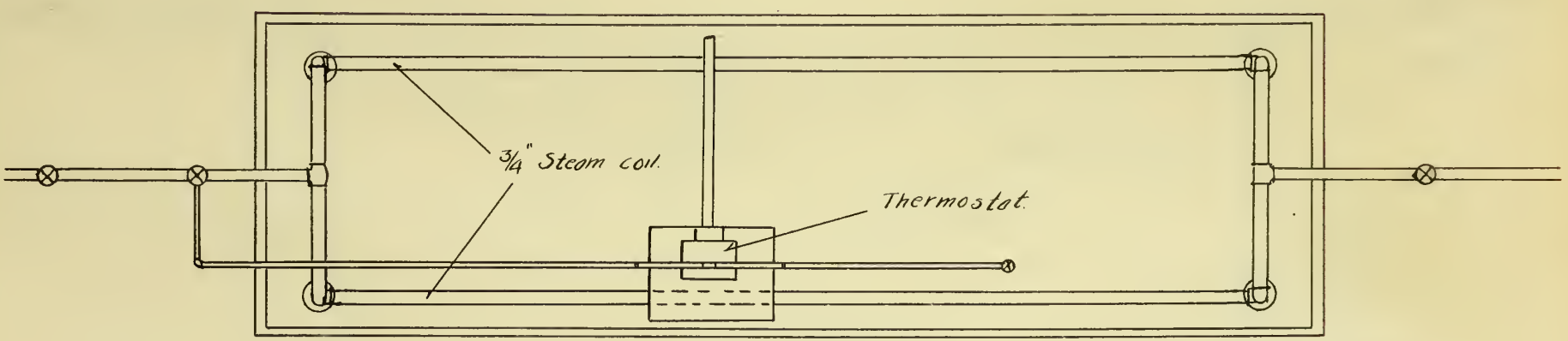


DIAGRAM OF APPARATUS.

ELEVATION

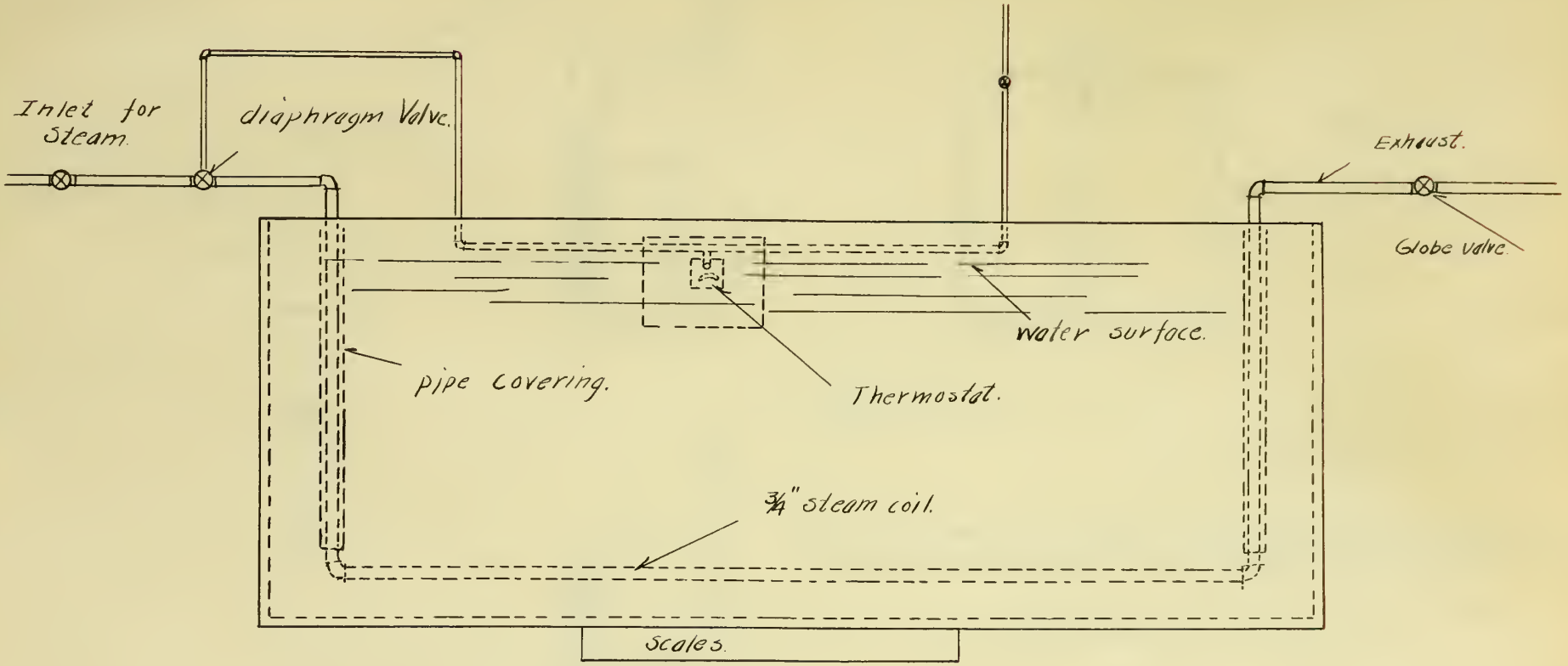
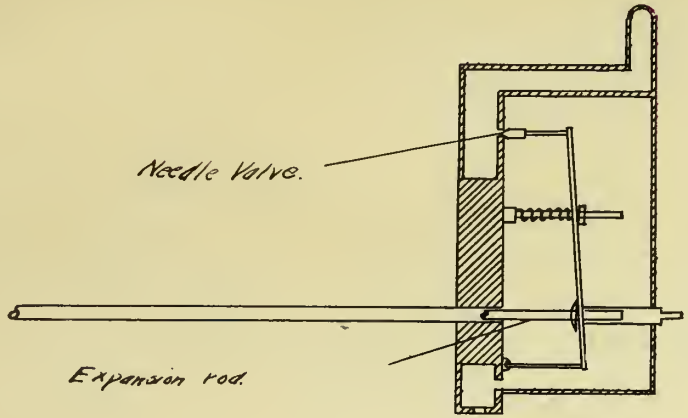
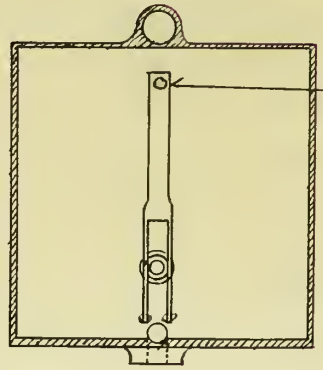


DIAGRAM OF THERMOSTAT.





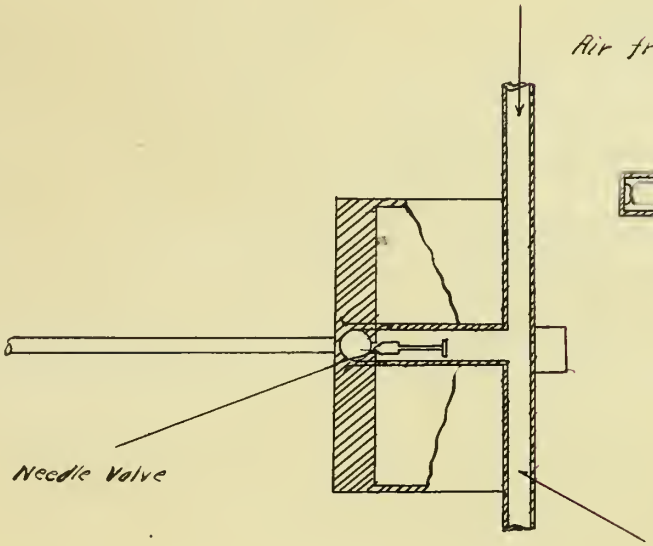


Diagram of Epansion rod.

The following data show the results of the tests:

Temperature °Fahr.		Difference in Temperatures	Diff. in wet and dry bulb readings	Evaporation	
				Total lb. per sq.ft. per hr.	In pounds per sq.ft per ° diff. in temp.per hour.
Water	Air				
90.4	72.7	17.7	11.3	0.0811	0.00505
116.1	71.9	44.2	8.6	0.2875	0.00650
115.0	69.5	45.5	9.3	0.2480	0.00545
141.9	69.5	72.4	8.6	0.669	0.00925
139.7	83.9	55.8	12.8	0.531	0.00967
139.9	83.0	56.9	13.0	0.479	0.00837
165.0	73.1	91.9	10.2	1.337	0.01454
165.4	83.9	81.5	11.9	1.049	0.01285
165.0	86.0	79.	11.8	1.188	0.01500
191.4	80.9	110.5	11.1	2.705	0.02448

TEST No. 1.

Tank No. 2. Water Surface = 16.52 square feet.

Average Barometer Reading = 29.706 inches.

May 5, 1911.

Time	Weight on Scales in Pounds.	Water Evaporated.			Temperatures in degrees F.		Difference in temp. of Air and Water in degrees F.	Hygrometer Readings in degrees F.			Relative Humidity of Air in Percent.
		Pounds.	Pounds per sq. ft. of Surface.	Pounds per sq. ft. per degree diff. in temp. of air and water.	Air.	Water.		Dry Bulb	Wet Bulb.	Difference	
1:00	2061.0	0.0	0.0		68.0	90.0	22.0	68.0	59.0	9.0	57
2:00	2059.5	1.5	0.0907	0.00443	70.5	91.0	20.5	70.5	58.0	12.5	46
3:00	2058.8	0.7	0.0424	0.00217	70.5	90.0	19.5	70.5	56.0	14.5	39
4:00	2056.9	1.8	0.1090	0.00589	71.5	90.0	18.5	71.5	58.0	13.5	44
5:00	2055.0	1.9	0.1149	0.00547	71.0	92.0	21.0	71.0	58.0	13.0	45
6:00	2053.5	1.5	0.0907	0.00549	73.5	90.0	16.5	73.5	60.0	13.5	45
7:00	2052.5	1.0	0.0605	0.00403	75.0	90.0	15.0	75.0	64.0	11.0	54
8:00	2051.25	1.25	0.0756	0.00560	76.0	89.5	13.5	76.0	66.0	10.0	61
9:00	2050.0	1.25	0.0756	0.00438	75.0	90.5	15.5	75.0	66.0	9.0	61
10:00	2048.75	1.25	0.0756	0.00438	75.0	90.5	15.5	75.0	65.5	9.5	61
11:00	2047.5	1.25	0.0756	0.00445	74.0	91.0	17.0	74.0	65.0	9.0	60
Average		1.34	0.0811	0.00505	72.7	90.4	17.7	72.7	61.4	11.3	52.1

TEST No. 2.

Tank No. 2. Water Surface = 16.52 square feet.

Average Barometer Reading = 29.536 inches.

May 3, 1911.

Time.	Weight on Scales in Pounds	Water Evaporated.			Temperatures in degrees F.		Difference in temp. of Air and Water in degrees F.	Hygrometer Readings in degrees F.			Relative Humidity of Air in Percent.
		Pounds.	Pounds per sq. ft. of Surface	Pounds per sq. ft. per degree diff. in temp. of air and water.	Air	Water.		Dry Bulb	Wet Bulb.	Difference	
3:50	2017.75	4.75			71.5	115.5	44.5	71.0	62.5	8.5	60
4:50	2013.00	4.75	0.287	0.00619	69.5	116.0	46.5	69.5	60.0	9.5	55
5:50	2008.25	4.75	0.287	0.00654	71.0	115.0	44.0	71.0	63.0	8.0	63
6:50	2003.75	4.50	0.272	0.00619	74.0	117.0	43.0	74.0	65.0	9.0	60
7:50	1998.75	5.00	0.302	0.00703	73.5	116.0	42.5	73.5	65.0	8.5	59
8:50	1994.00	4.75	0.287	0.00668	73.0	116.0	43.0	73.0	64.0	9.0	61
9:50	1989.00	5.00	0.302	0.00672	72.0	117.0	45.0	72.0	64.0	8.0	65
10:50	1984.50	4.50	0.272	0.00606	71.0	116.0	45.0	71.0	63.0	8.0	57
Average		4.75	0.2875	0.00650	71.9	116.1	44.2	71.9	63.3	8.6	60

Test No. 3.

Tank No. 1. Water Surface = 26.35 square feet.

Average Barometer Reading = 29.295 inches.

April 21, 1911.

Time	Weight on Scales in Pounds.	Water Evaporated.			Temperatures in degrees F.		Difference in temp. of Air and Water in degrees F.	Hygrometer Readings in degrees F.			Relative Humidity of Air in Percent.
		Pounds.	Pounds per sq. ft. of Surface	Pounds per sq. ft. per degree diff. in temp. of Air and Water.	Air.	Water.		Dry Bulb.	Wet Bulb.	Difference	
9:00	3045.75				68.0	115.0	47.0	68.0	62.0	7.0	67
10:00	3039.2	6.55	0.248	0.00543	68.5	115.2	46.7	68.5	62.5	7.5	67
11:00	3033.1	6.1	0.231	0.00515	70.0	115.0	45.0	70.0	62.5	9.0	63
12:00	3026.9	6.2	0.235	0.00526	70.0	114.7	44.7	70.0	61.5	10.0	59
1:00	3020.4	6.5	0.246	0.00555	70.5	115.0	44.5	70.5	63.0	9.0	62
2:00	3014.2	6.2	0.235	0.00535	71.0	115.0	44.0	71.0	64.0	11.0	55
3:00	3007.9	6.3	0.239	0.00517	69.0	115.3	46.3	69.0	60.0	11.5	50
4:00	3001.2	6.7	0.254	0.00565	70.0	115.0	45.0	70.0	60.5	10.0	54
5:00	2994.5	6.7	0.254	0.00555	69.0	114.8	45.8	69.0	60.5	10.0	54
6:00	2986.6	7.9	0.300	0.00625	67.0	115.0	48.0	67.0	61.2	8.3	68
7:00	2980.5	6.1	0.231	0.00525	70.5	115.0	44.5	70.5	64.5	8.5	57
Average		6.53	0.248	0.00545	69.5	115.0	45.5	69.5	62.0	9.3	59.6

TEST NO. 4.

Tank No. 2. Water Surface = 16.52 square feet.

Average Barometer Reading = 29.104 inches.

May 1, 1911.

Time	Weight on Scales in	Water Evaporated.			Temperatures in degrees F.		Difference in temp. of air and water in degrees F.	Hygrometer Readings in degrees F.			Relative Humidity of Air in Percent.
		Pounds	Pounds per sq. ft. of Surface.	Pounds per sq. ft. per degree diff. in temp. of air and water.	Air	Water.		Dry Bulb.	Wet Bulb.	Difference	
2:00	1967.25				69.0	142.0	73.0	69.0	60.5	9.0	58.5
3:00	1956.50	10.75	0.650	0.00956	73.0	141.0	68.0	73.0	64.5	8.5	64.0
4:00	1944.20	12.3	0.745	0.01040	70.0	141.5	71.5	70.0	61.5	8.5	61.0
5:00	1932.6	11.6	0.703	0.00976	70.0	142.0	72.0	70.0	61.5	8.5	61.0
6:00	1921.7	10.9	0.660	0.00886	68.0	142.5	74.5	68.0	60.5	7.5	62.0
7:00	1910.7	11.0	0.666	0.00906	68.5	142.0	73.5	68.5	60.0	8.5	62.0
8:00	1899.8	10.9	0.660	0.00886	68.0	142.5	74.5	68.0	58.0	10.0	55.0
Average		11.08	0.669	0.00925	69.5	141.9	72.4	69.5	60.9	8.6	60.5

Test No. 5.

Tank No. 2. Water Surface = 16.52 square feet.

Average Barometer Reading = 29.378 inches.

May 8, 1911.

Time	Weight on Scales in Pounds.	Water Evaporated.			Temperatures in degrees F.		Difference in Temp. of Air and Water in degrees F.	Hygrometer Readings in degrees F.			Relative Humidity of air in Percent.
		Pounds.	Pounds per sq. ft. of Surface	Pounds per sq. ft. per degree diff. in temp. of air and water.	Air.	Water.		Dry Bulb.	Wet Bulb.	Difference	
3:40	2012.0				87.0	140.5	53.6	87.0	73.0	14.0	50
4:40	2002.5	9.5	0.575	0.01074	86.0	139.5	53.5	86.0	70.0	16.0	45
5:40	1993.0	9.5	0.575	0.01065	84.0	138.0	54.0	84.0	70.0	14.0	49.5
6:40	1984.5	8.5	0.514	0.00923	84.3	140.0	55.7	84.3	72.0	12.3	55
7:40	1976.4	8.1	0.490	0.00883	84.5	140.0	55.5	84.5	72.0	12.5	55
8:40	1967.6	8.8	0.532	0.00903	81.5	140.5	59.0	81.5	71.0	10.5	60
9:40	1957.5	8.9	0.573	0.00955	80.0	140.0	60.0	80.0	70.0	10.0	60.5
Average		8.88	0.531	0.00967	83.9	139.7	55.8	83.9	71.1	12.8	53.5

TEST No. 6.

Tank No. 3. Water Surface = 23.51 square feet.

Average Barometer Reading = 29.470 inches.

May 12, 1911.

Time.	Weight on Scales in Pounds.	Water Evaporated.			Temperatures in degrees F.		Difference in temp. of air and water in degrees F.	Hygrometer Readings. in degrees F.			Relative Humidity of Air in Percent.
		Pounds	Pounds per sq. ft. of Surface	Pounds per sq.ft. per degree diff. in temp. of air and water	Air	Water.		Dry Bulb.	Wet Bulb.	Difference	
2:30	2247.75	11.50			82.0	140.0	58.0	82.0	68.5	13.5	50.5
3:30	2236.25	11.50	0.489	0.00870	84.0	140.0	56.0	84.0	69.0	15.0	46
4:30	2225.00	11.25	0.478	0.00855	83.5	139.5	56.0	83.5	68.0	15.5	46.5
5:30	2214.00	11.00	0.468	0.00807	82.0	140.0	58.0	82.0	68.0	14.0	48
6:30	2203.50	10.50	0.447	0.00770	82.0	140.0	58.0	82.0	74.0	8.0	67.5
7:30	2191.70	11.80	0.502	0.00897	84.0	140.0	56.0	84.0	71.5	12.5	54
8:30	2180.10	11.60	0.494	0.00874	83.5	140.0	56.5	83.5	71.0	12.5	55.5
Average		11.26	0.479	0.00837	83.0	139.9	56.9	83.0	70.0	13.0	52.5

Test No. 7.

Tank No. 2. Water Surface = 16.48 square feet.

Average Barometer Reading = 29.494 inches.

May 2, 1911.

Time	Weight on Scales in Pounds.	Water Evaporated.			Temperatures in degrees F.		Difference in temp. of air and water in degrees F.	Hygrometer Readings in degrees F.			Relative Humidity of air in Percent.
		Pounds	Pounds per sq. ft. of Surface	Pounds per sq. ft. per degree diff. in temp. of air and water.	Air	Water		Dry Bulb.	Wet Bulb.	Difference	
4:15	1984.0				74.0	166.5	92.5	74.0	62.5	11.5	53
5:15	1962.75	21.25	1.290	0.01449	76.0	165.0	89.0	76.0	63.0	13.0	51
6:15	1941.0	21.75	1.320	0.01450	73.0	164.0	91.0	73.0	63.0	10.0	56
7:15	1919.0	22.0	1.335	0.01460	73.0	164.5	91.5	73.0	63.0	10.0	56
8:15	1897.0	22.3	1.352	0.01462	73.0	165.5	92.5	73.0	63.0	10.0	56
9:15	1875.0	22.7	1.378	0.01481	72.0	165.0	93.0	72.0	63.5	8.5	60
10:15	1853.0	22.0	1.335	0.01429	71.0	164.5	93.5	71.0	62.0	9.0	60
Average		22.0	1.337	0.01454	73.1	165.0	91.9	73.1	62.8	10.2	56

TEST No. 8.

Tank No. 3. Water Surface = 23.51 square feet.

Average Barometer Reading = 29.625 inches.

May 13, 1911.

Time.	Weight on Scales in Pounds.	Water Evaporated			Temperatures in degrees F.		Difference in temp. of air and water in degrees F.	Hygrometer Readings in degrees F			Relative Humidity of Air in Percent
		Pounds.	Pounds per sq. ft. of Surface	Pounds per sq. ft. per degree diff. in temp. of air and water.	Air	Water		Dry Bulb	Wet Bulb	Difference	
11:10	2416.75				79.5	165.0	85.5	79.5	67.5	12.0	55.5
12:10	2390.25	26.50	1.128	0.01335	81.5	166.0	84.5	81.5	67.5	14.0	50.
1:10	2364.50	25.75	1.095	0.01322	82.5	165.5	83.0	82.5	68.0	14.5	48.5
4:30	2281.50				85.0	165.5	80.5	85.0	76.0	9.0	66.
5:30	2257.6	23.9	1.017	0.01295	86.5	165.0	78.5	86.5	74.0	12.5	57
6:30	2235.1	22.5	0.957	0.01267	90.0	165.5	75.5	90.0	77.0	13.0	55
7:30	2210.9	24.2	1.029	0.01225	82.0	166.0	84.0	87.0	75.0	12.0	55
8:30	2186.0	24.9	1.059	0.01308	84.0	165.0	81.0	84.0	74.0	10.0	61
Average		24.62	1.049	0.01285	83.9	165.4	81.5	84.5	72.6	11.9	56

TEST No. 9.

Tank No. 2. Water Surface = 16.48 square feet.

Average Barometer Reading = 29.050 inches.

May 10, 1911.

Time.	Weight on Scales in Pounds.	Water Evaporated.			Temperatures in degrees F.		Difference in temp. of air and water in degrees F.	Hygrometer Readings in degrees F.			Relative Humidity of Air in Percent
		Pounds.	Pounds per sq. ft. of Surface.	Pounds per sq. ft. per degree diff. in temp. of air and water.	Air	Water.		Dry Bulb.	Wet Bulb.	Difference	
2:40	2037.75				88.0	165.0	77.0	88.0	76.0	12.0	58
3:40	2019.50	18.25	1.109	0.01440	88.0	165.0	77.0	88.0	75.0	13.0	55
4:40	1999.25	20.25	1.230	0.01590	88.0	165.3	77.3	88.0	74.5	13.5	54
5:40	1979.75	19.50	1.183	0.01499	86.0	165.0	79.0	86.0	73.5	12.5	54
6:40	1959.75	20.00	1.215	0.01556	87.0	165.0	78.0	87.0	75.0	12.0	56
7:40	1940.00	19.75	1.200	0.01467	83.0	164.8	81.8	83.0	73.0	10.0	62
8:40	1920.50	19.50	1.185	0.01427	82.0	165.0	83.0	82.0	72.5	9.5	64
Average		19.56	1.188	0.01500	86.0	165.0	79.0	86.0	74.2	11.8	57.6

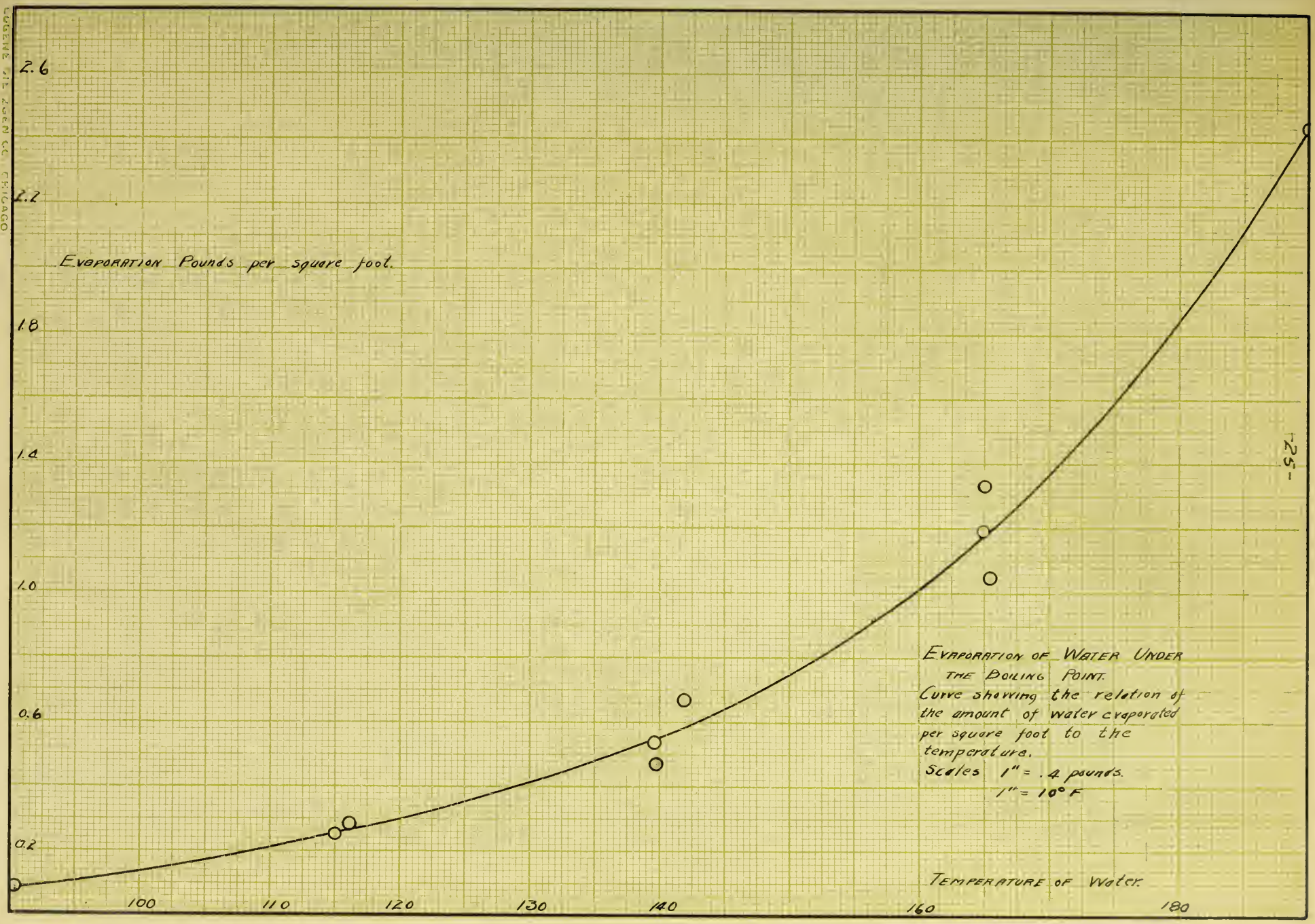
TEST No. 10.

Tank No. 2. Water Surface = 16.48 square feet.

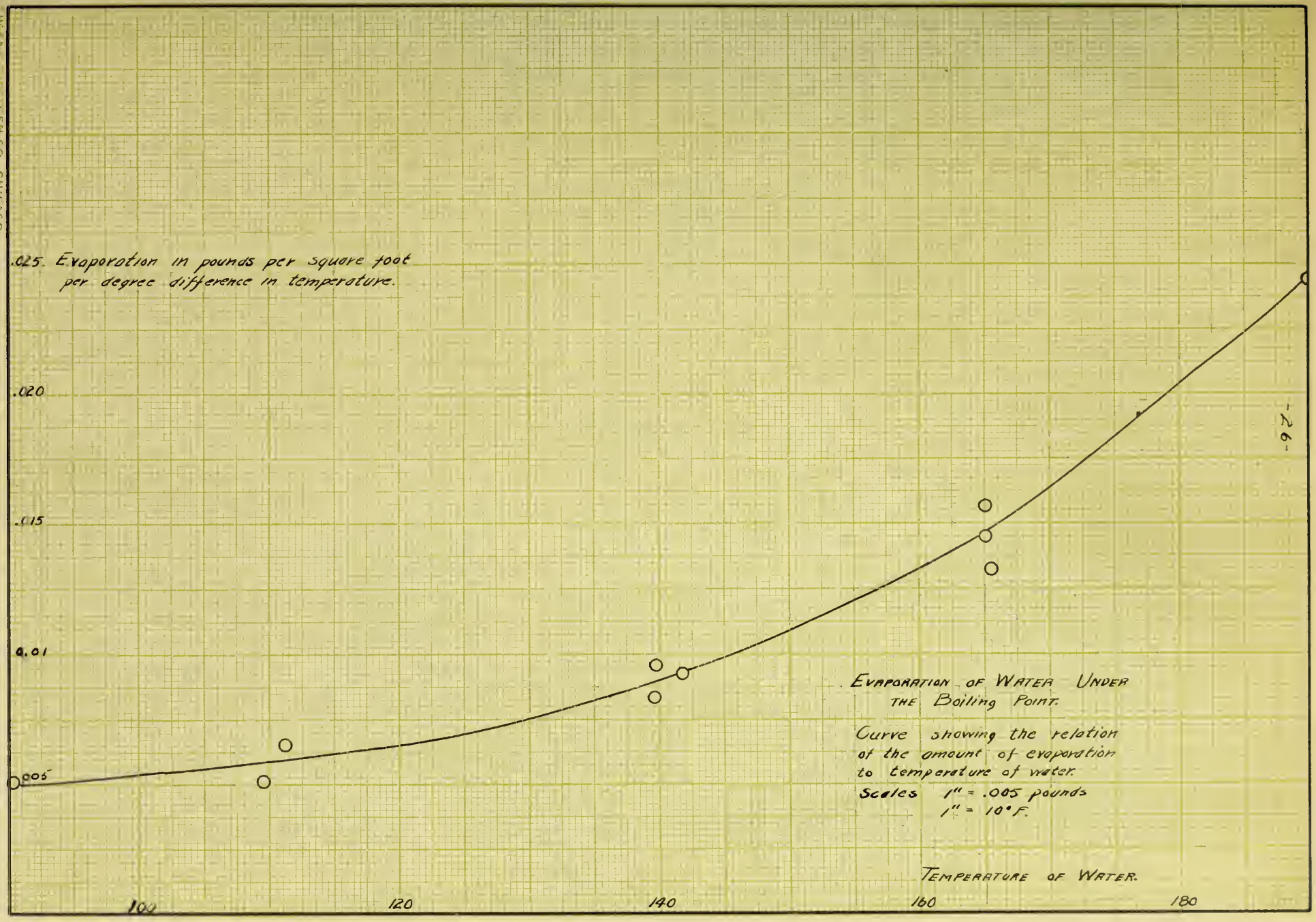
Average Barometer Reading = 29.668 inches.

May 6, 1911.

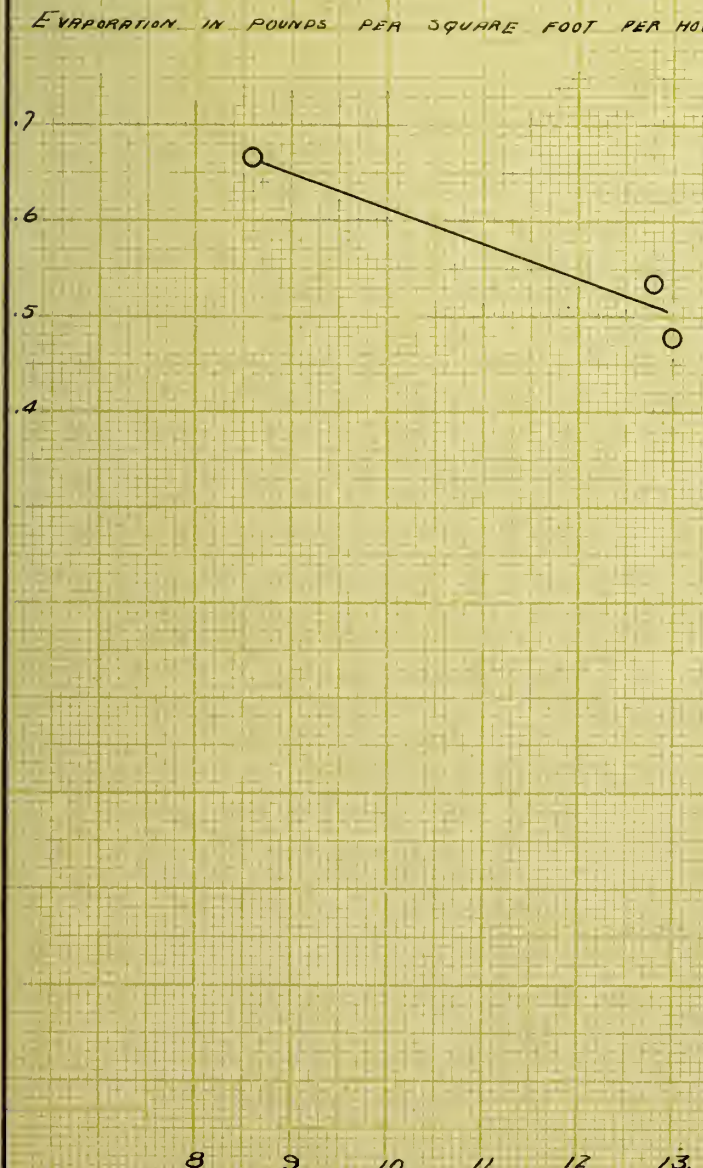
Time.	Weight on Scales in Pounds.	Water Evaporated.			Temperatures in degrees F.		Difference in temp of air and water in degrees F.	Hygrometer Readings in degrees F.			Relative Humidity of Air in Percent.
		Pounds.	Pounds per sq. ft. of Surface.	Pounds per sq. ft. per degree diff. in temp. of air and water.	Air	Water.		Dry Bulb	Wet Bulb.	Difference	
2:55	2026.8				80.0	190.0	110.0	80.0	67.0	13.0	51
3:55	1976.2	50.6	3.07	0.0266	77.5	193.0	115.5	77.5	61.5	16.0	41
4:55	1929.6	46.6	2.83	0.0248	78.0	192.0	114.0	78.0	66.5	11.5	56
5:55	1886.5	43.1	2.68	0.0239	82.5	192.0	109.5	82.5	71.5	11.0	59
6:55	1845.2	41.3	2.51	0.0229	82.5	190.0	109.5	82.5	73.0	9.5	64
7:55	1801.3	43.9	2.66	0.0243	82.5	192.0	109.5	82.5	72.5	10.0	61
8:55	1756.1	45.2	2.74	0.0247	82.0	193.0	111.0	82.0	73.5	8.5	67
9:55	1714.2	41.9	2.54	0.0232	82.0	191.0	109.0	82.0	73.0	9.0	66
Average		44.6	2.705	0.02448	80.9	191.4	110.5	80.9	69.8	11.1	58.1



KEUFFEL & ESSER CO. CHICAGO



UGEN CO., CHICAGO.

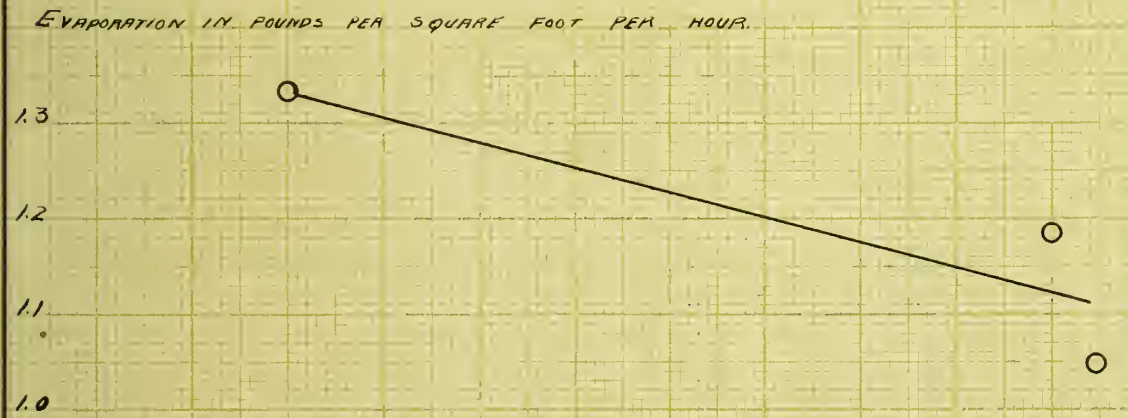


Evaporation of Water Under the Boiling Point.

Curve showing the relation of the evaporation to the wet and dry bulb readings. for tests 4, 5 and 6.

Scales 1" = .2 pounds
1" = 2° F.

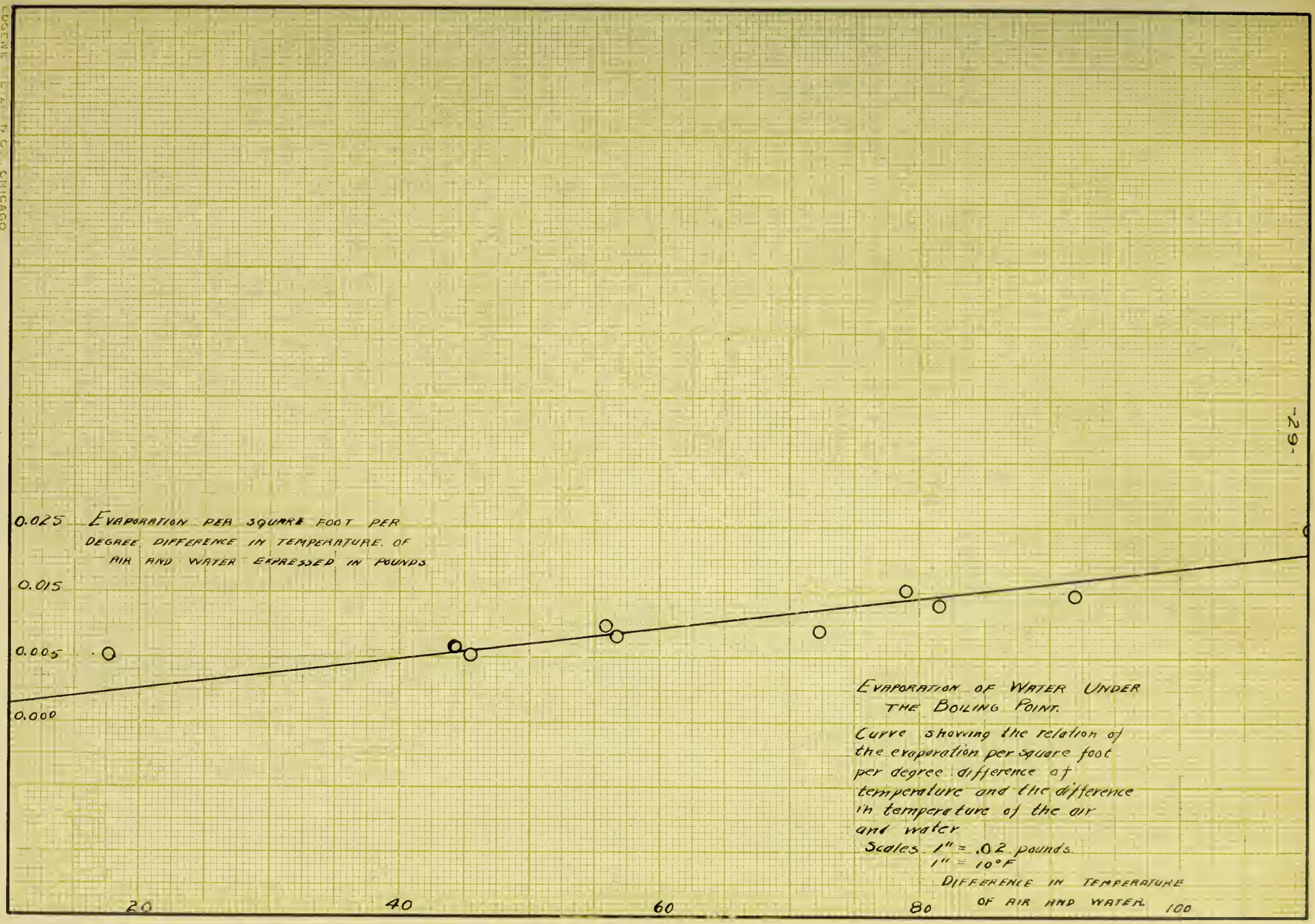
EUGENE DIETZGEN CO., CHICAGO



Evaporation of Water Under the Boiling Point.

Curve showing the relation of the evaporation to the difference of the wet and dry bulb readings for tests 7, 8 and 9.

Scales 1" = .2 pounds.
1" = .4°F



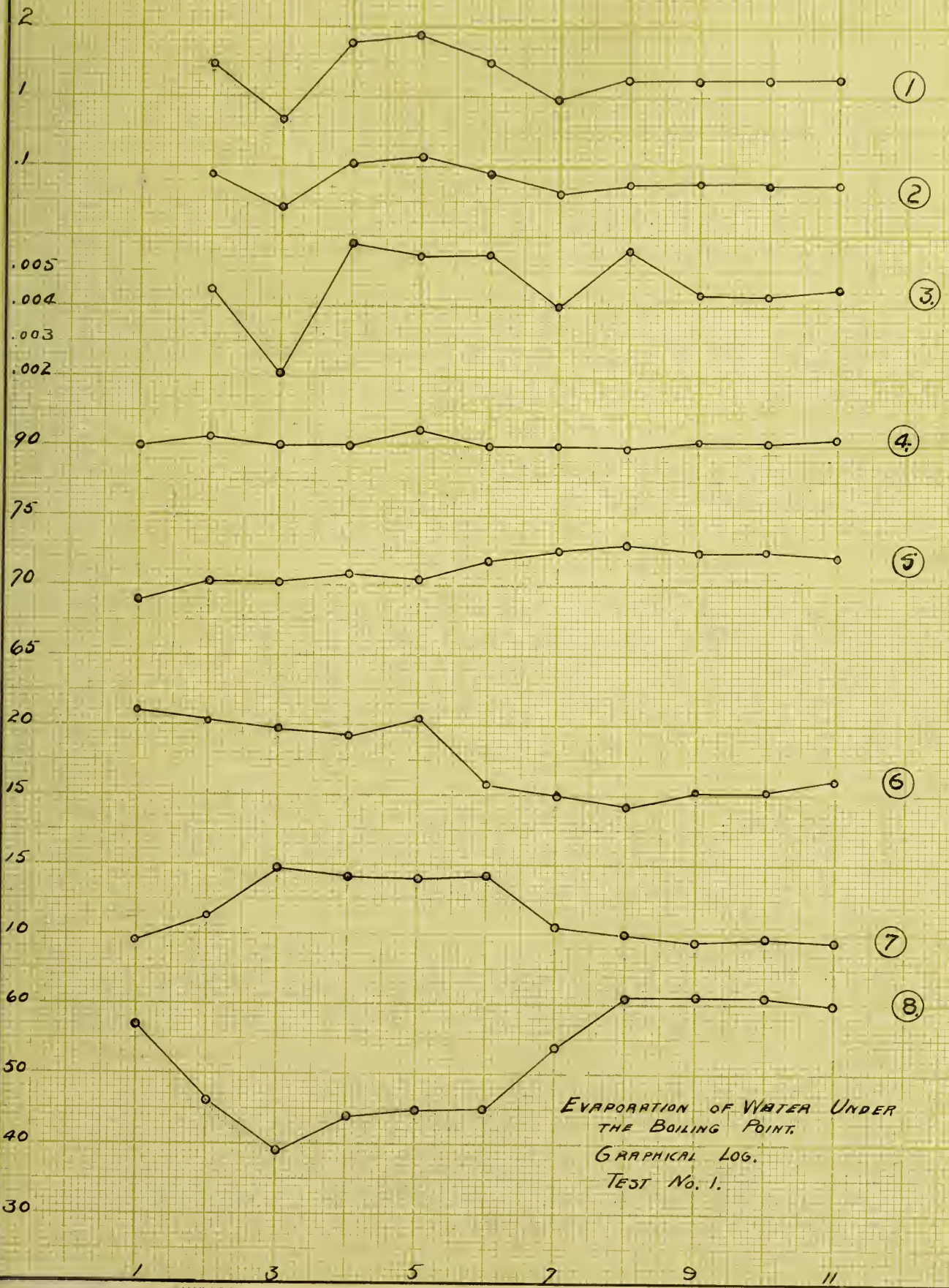
Evaporation of Water Under the Boiling Point.

Curve showing the relation of the evaporation per square foot per degree difference of temperature and the difference in temperature of the air and water.

Scales 1" = .02 pounds.
1" = 10°F

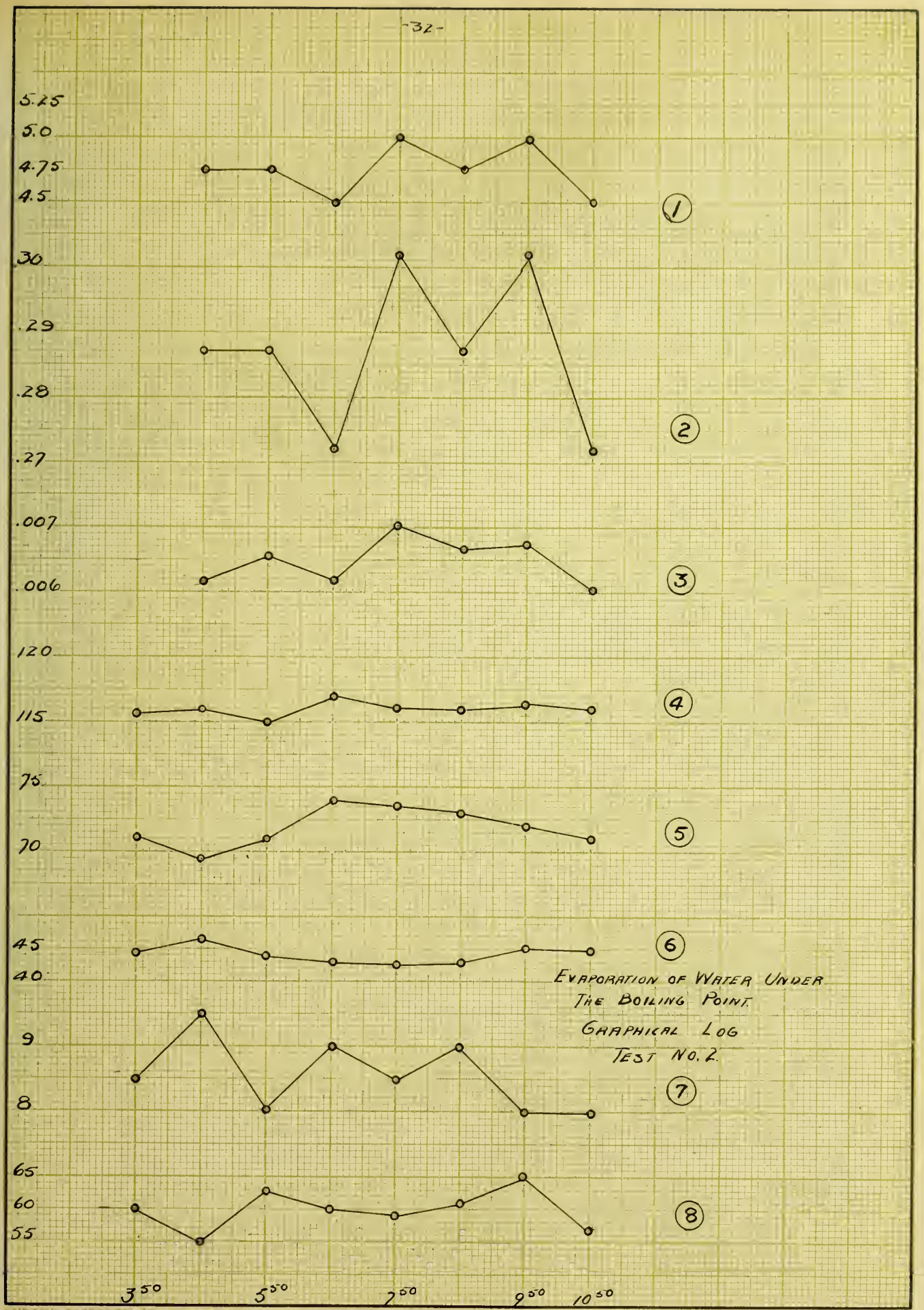
THE CURVES ON THE FOLLOWING GRAPHICAL LOGS ARE:

1. Pounds of water evaporated.
2. Pounds of water evaporated per squaro foot.
3. Pounds of water evaporated per square foot per degree difference of temperature of air and water.
4. Temperature of water.
5. Temperature of air.
6. Difference of tenperature of air and water.
7. Difference of temperature of wet and dry bulbs.
8. Relative humidity.



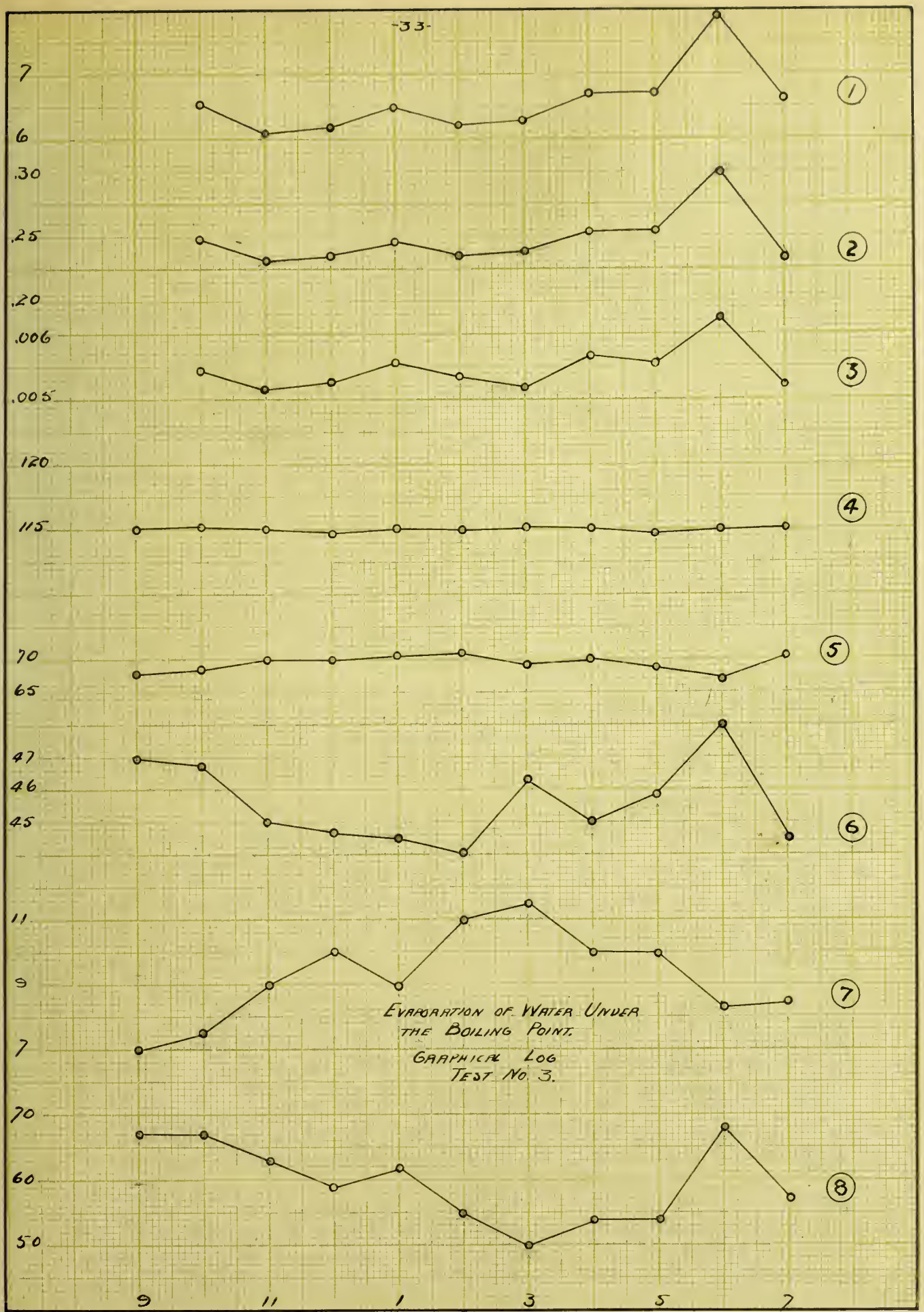
EVAPORATION OF WATER UNDER THE BOILING POINT.
GRAPHICAL LOG.
TEST No. 1.

HICAGO.



Evaporation of Water Under The Boiling Point.
Graphical Log
Test No. 2.

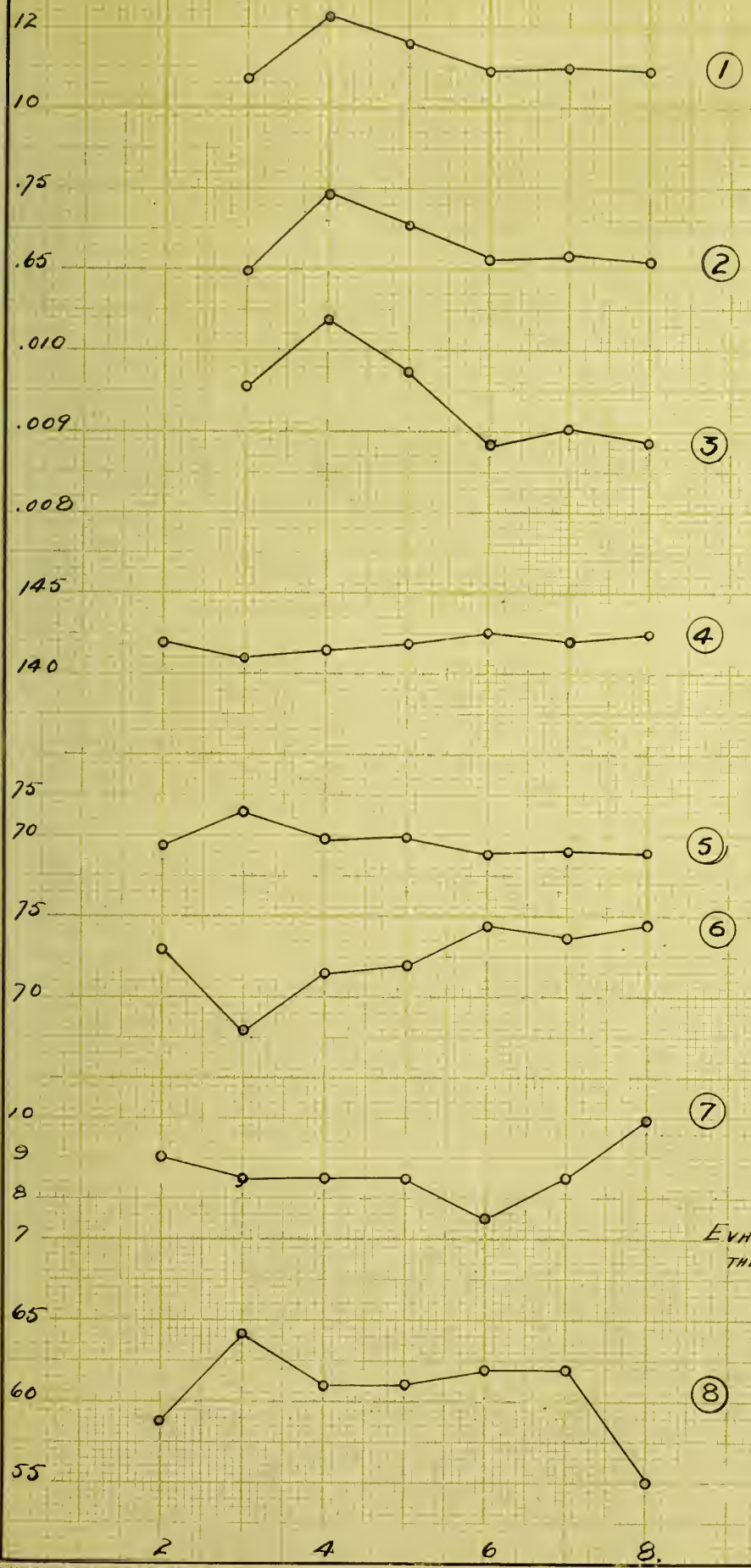
EUGENE DIETZGEN CO. CHICAGO.



Evaporation of Water Under the Boiling Point.

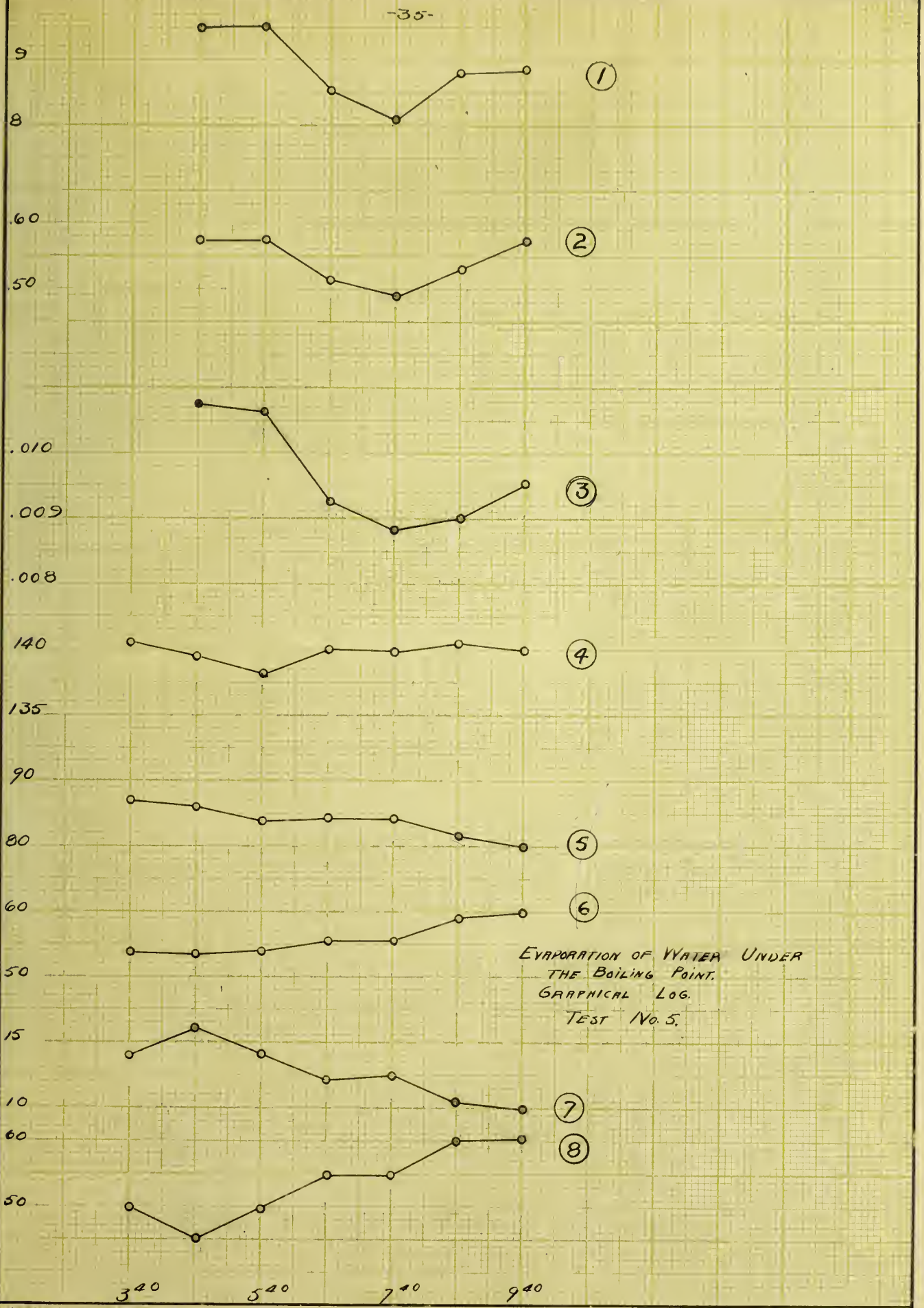
Graphical Log
Test No. 3.

EUGENE DIETZGEN CO., CHICAGO.

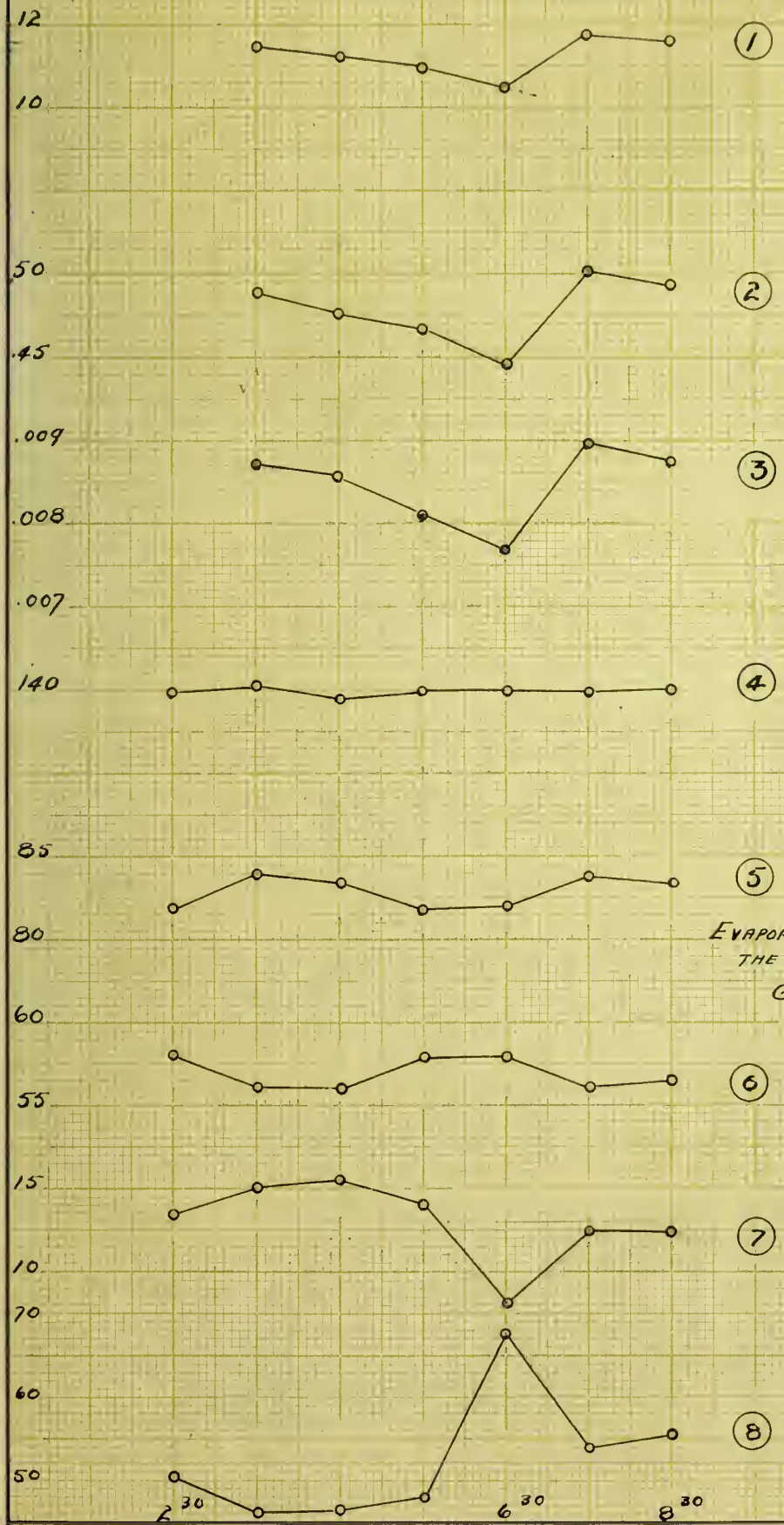


Evaporation of Water Under the Boiling Point.
Graphical Log.
Test No. 4.

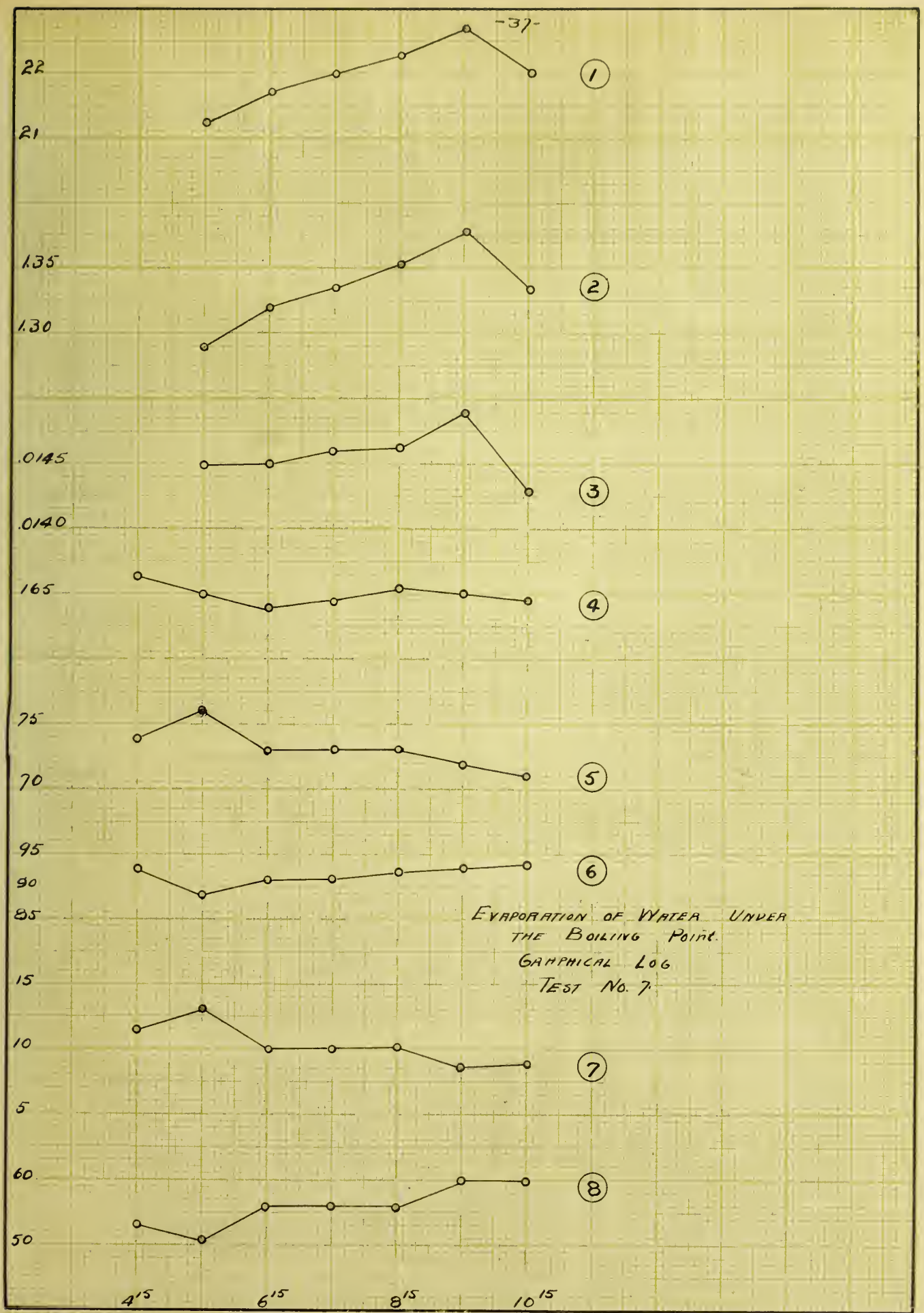
CUSHING PUB. CO. CHICAGO.



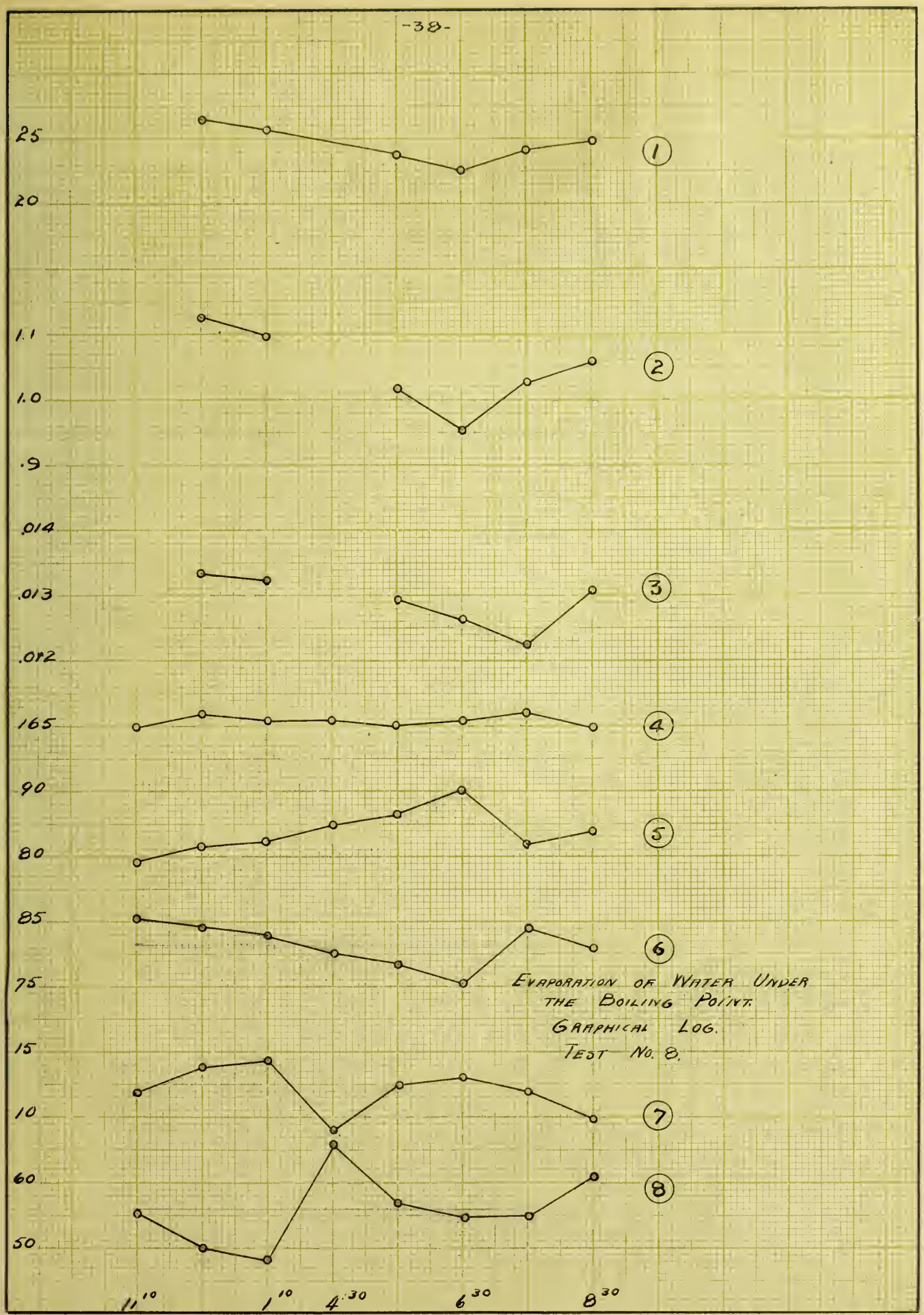
Evaporation of Water Under the Boiling Point.
Graphical Log.
Test No. 5.



Evaporation of Water Under the Boiling Point.
Graphical Log.
Test No. 6

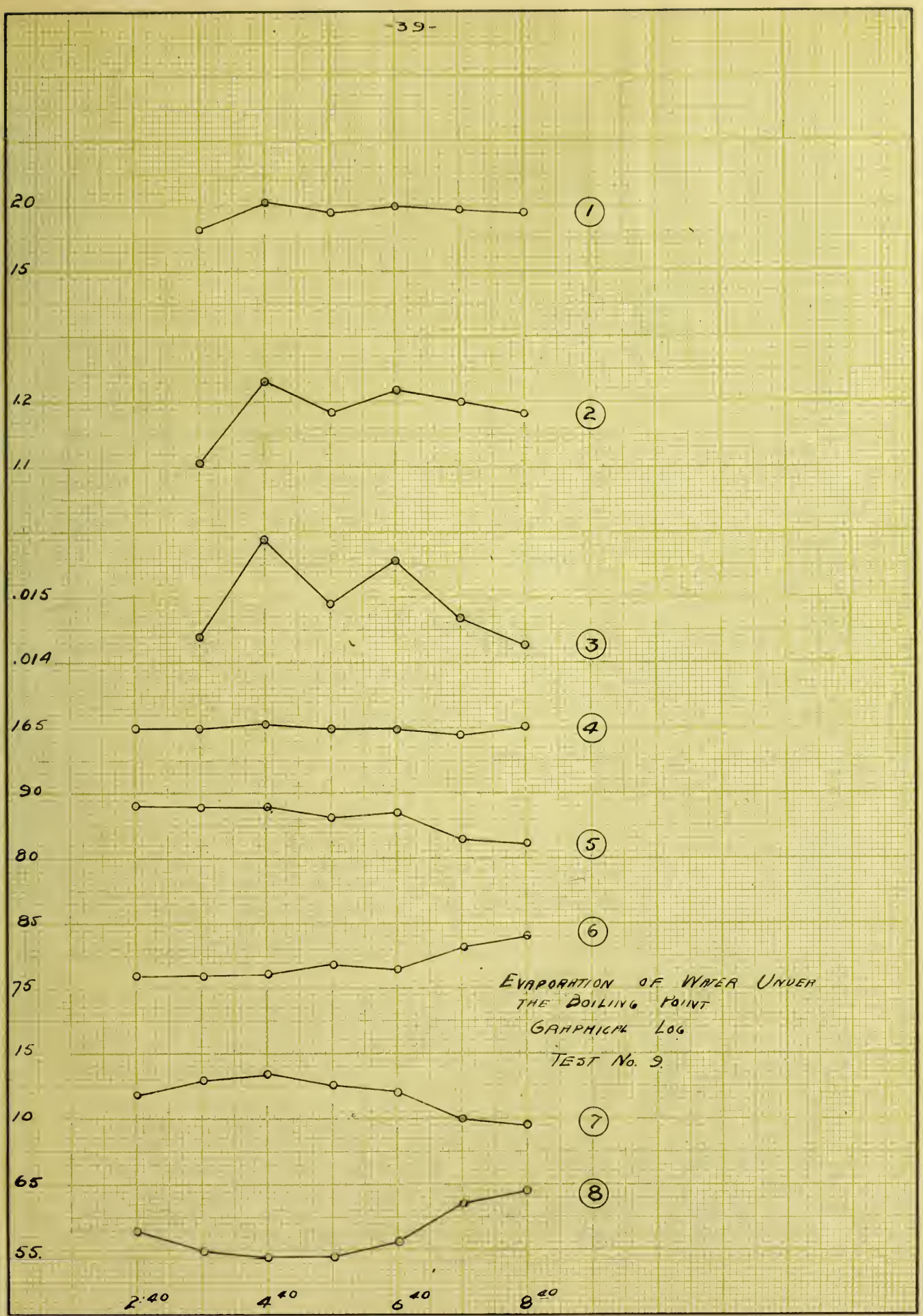


EVAPORATION OF WATER UNDER THE BOILING POINT.
GRAPHICAL LOG
TEST NO. 7.

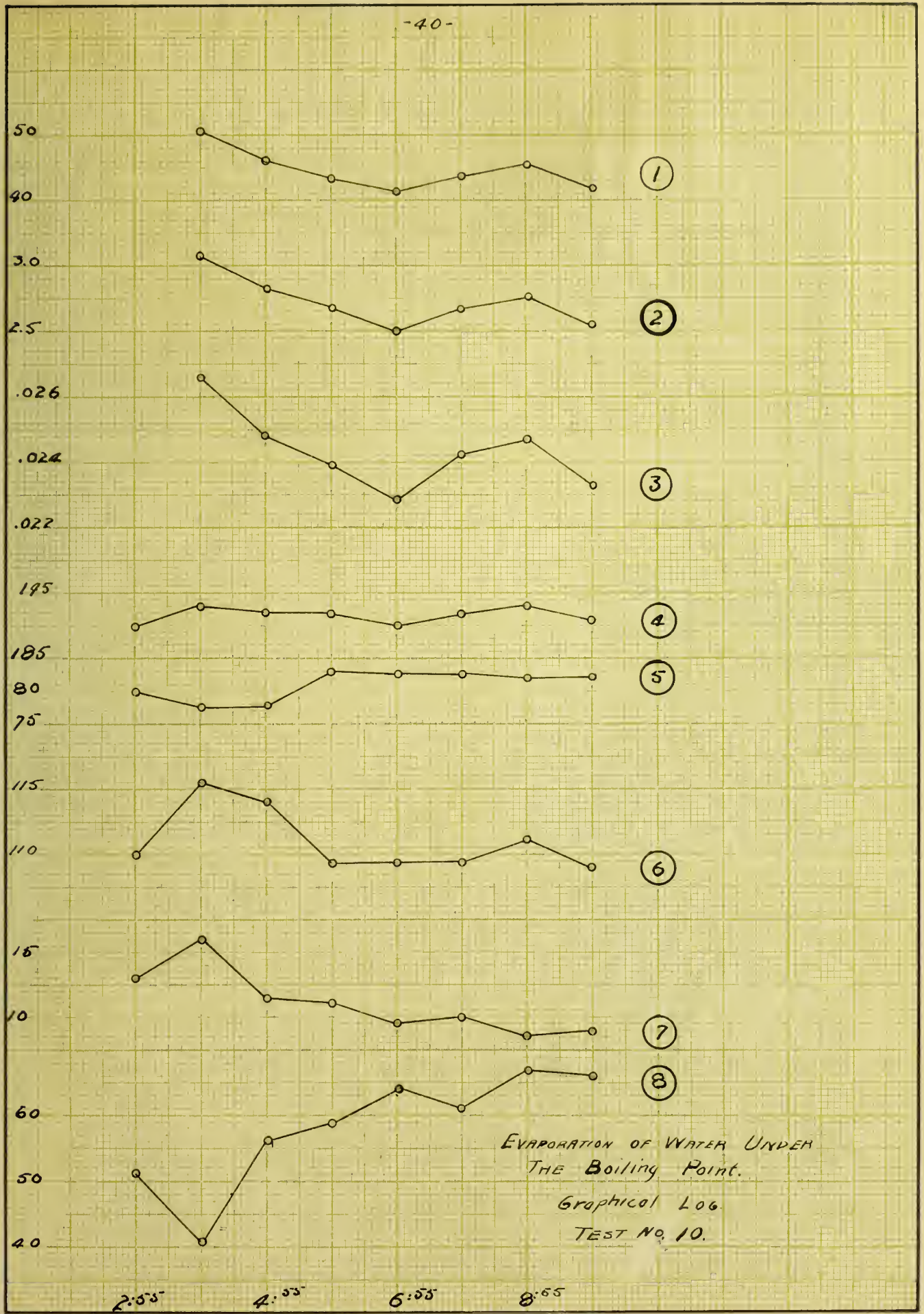


Evaporation of Water Under the Boiling Point.
Graphical Log.
Test No. 8.

ENGEN ... CO. CHICAGO



EVAPORATION OF WATER UNDER THE BOILING POINT
GRAPHICAL LOG
TEST No. 9.



EVAPORATION OF WATER UNDER THE BOILING POINT.

GRAPHICAL LOG.

TEST NO. 10.

CHICAGO.